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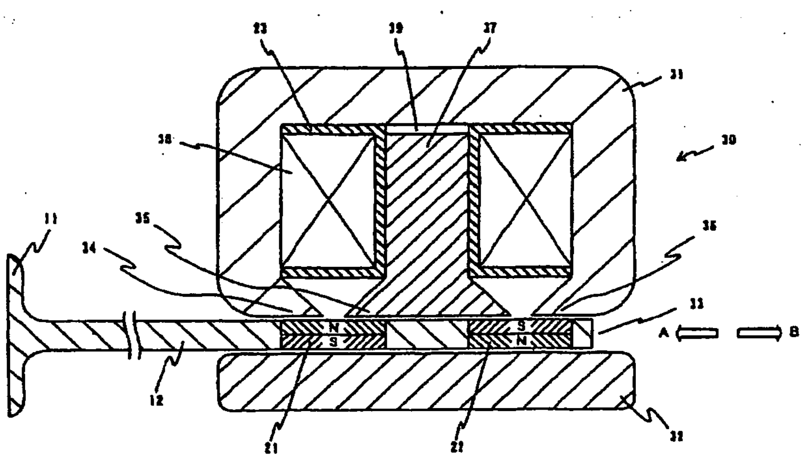
(54) **VALVE DRIVING DEVICE**

(57) A valve driving apparatus includes a magnetic flux generating element in which an electromagnetic coil is wound to generate magnetic flux, a magnetic field generating element which has at least two poles to distribute magnetic flux and form at least one magnetic field region, a drive means which includes a magnetic path member, and a magnetized member arranged in accordance with the magnetic field region and having two magnetized faces with mutually different polarity to be connected and moved together with a valve rod united with a valve element. A current supply means supplies driving current to the electromagnetic coil whereby the current has polarities corresponding to either a valve closing direction or a valve opening direction of the valve element. The apparatus reduce impact of valve seating with a simple structure and controls the valve with less power consumption and with precision.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] This invention relates to a valve driving apparatus which drives a valve element to control the flow of intake gas or exhaust gas of an internal combustion engine.

Description of the Related Art

[0002] An electromagnetic valve drive apparatus controlling the opening and closing of valves by electromagnetic force is known as an apparatus driving valve bodies such as intake valves or exhaust valves which controls the flow of intake gas or exhaust gas of an internal combustion engine. This apparatus does not control the valve opening and closing by a cam which is rotatably driven by a crankshaft, but is capable of controlling the valve opening and closing and its timing regardless the cam configuration and cam rotational speed. However, by increasing the opening and closing speed of the valve, the valve is liable to collide with its surrounding member at the time of the valve seating and, as a result, ther arise problems such as abrasion of the valve and its surrounding member and generation of impulsive sounds. For example, an apparatus disclosed in Japanese Patent Kokai No.10-141028 is provided with an air damper mechanism in the valve driving apparatus in order to reduce shocks at the valve seating timing, thereby solving these problems. However, this valve driving apparatus has a complex structure thereby creating a new problem.

[0003] Also, the valve driving apparatus in which th valves are driven by electromagnetic force needs a power supply to drive the apparatus, and conservation of the power consumption is also required. The apparatus which is disclosed in Japanese Patent Kokai No.8-189315 attempts to conserve power by changing the valve travel distance according to the internal combustion engine driving condition. However, the reduction of the supplied power has caused new problems such as reduced driving force and decreased response characteristics of valve opening and closing.

[0004] Furthermore, in the apparatus which is disclosed in Japanese Patent No. 2,772,569, the valve driving force has been increased by arranging a plurality of fixed magnetic poles and controlling the current magnitude supplied to the energizing coil. However, this apparatus has caused the structure to become complex and increase of power consumption, to create problems.

[0005] As discussed above, the conventional electromagnetic valve driving apparatus which attempts to reduce the shock of the valve when the valve is seated requires a complex structure and increases power consumption in order to precisely control valve movement. Further, with regard to the conventional valve driving apparatus which applies soft f rromagnetic iron material to the moving element, it is also a problem to align the valve to a predetermined position when power to the valve driving apparatus is not applied.

[0006] The present invention has been devised in view of the foregoing problems and an object of the invention is to provide an electromagnetic force driven apparatus whereby the structure is simple and the valve seating shock is reduced. Further, valve control is precisely executed with low power consumption thereby enabling the valve to be placed at a predetermined position when power to the valve driving apparatus is not applied.

OBJECTS AND SUMMARY OF THE INVENTION

[0007] The valve driving apparatus of the present invention is a valve driving apparatus for driving a valve element controlling intake gas flow or exhaust gas flow of an internal combustion engine which is characterized by: driving means including a magnetized path member comprising a magnetic flux generating element in which an electromagnetic coil is wound to generates magnetic flux and a magnetic field generating element comprising at least two pole members to distribute said magnetic flux to form at least one magnetic field, a magnetizing member moving within said magnetic field in cooperation with a valve rod formed integrally with said valve element, said member having two magnetized surfaces with mutually different polarities, current supply means for supplying a driving current to said electromagnetic coil corresponding to the poles of either a valve opening direction or a valve closing direction of said valve element.

[0008] Therefore, the objects if the present invention is to simplify the structure of the apparatus and to reduce the shock when the valve is seated.

BRIEF EXPLANATION OF THE DRAWINGS

[0009]

Figure 1 is a sectional view showing a first embodiment of the valve driving apparatus of the present invention. Figure 2 is an enlarged exploded view of the valve driving apparatus shown in Figure 1. Figure 3 is a graph showing the relationship between the moving distance of the magnetized member and the driving force applied to the magnetized member. Figure 4 is a graph showing the relationship between the time to move the magnetized member under optimized control, position of the magnetized member and the acceleration thereof. Figure 5 is a sectional view of the combustion chamber region wherein the valve driving apparatus shown in Figure 1 is applied to the intake valve

and the exhaust valve of the driving apparatus. Figure 6 is a sectional view showing a second embodiment of the valve driving apparatus. Figure 7 is a sectional view showing a third embodiment of The valve driving apparatus. Figure 8 is a sectional view showing a forth embodiment of the valve driving apparatus. Figure 9 is a sectional view showing a fifth embodiment of the valve driving apparatus. Figure 10 is an enlarged perspective view of the yoke and the magnetized member of the valve driving apparatus shown in Figure 9. Figure 11 is a perspective view showing a sixth embodiment of the valve driving apparatus. Figure 12 is a perspective view showing the valve driving apparatus of Figure 11 wherein the upper frame, lower frame and coil are omitted. Figure 13 is a perspective view showing the upper frame viewed from below. Figure 14 is a perspective view showing the yoke held between lower frame portions. Figure 15 is a perspective view showing the magnetized member and the moving element. Figure 16 is an enlarged perspective view showing the state in which the roller engages the edge of the protruded portion of the moving element and the lower frame guide groove. Figure 17 is a sectional view along line X-X, shown in Figure 11. Figure 18 is a sectional view along line Y-Y, shown in Figure 11. Figure 19 is an enlarged perspective view showing the state in which the spheroid engages the edge of the protruded portion of the moving element and the lower frame guide groove. Figure 20 is an enlarged perspective view showing the fitting portion of the moving element and the valve element.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0010] Embodiments of the present invention will now be described with reference to the drawings.

[0011] Figure 1 shows a first embodiment of the valve driving apparatus of the present invention.

[0012] Valve 11 is integrally formed at one end of valve rod 12. The region of the other end portion of the valve rod 12 has a rectangular sectional configuration and through holes 13 and 14 are arranged therein, as shown in Figure 2. Two magnetizing members 21 and 22 having their thickness as the valve rod 12 are inserted into the through holes 13 and 14, so that upper surfaces and lower surfaces of the magnetizing member are in planer alignment with the upper surface and the lower surface of the valve rod 12, respectively. The two magnetized members 21 and 22 are respectively arranged so that the opposing faces have a different magnetic polarity to each other. Magnetized members 21 and 22 are arranged so that the polarity of two sides of magnetized member 21 have an polarity when compared to two sides of magnetized member 22. Along one side of yoke 31 of th actuator 30, three poles 34, 35 and 36 are in parallel alignment in the lengthwise direction of the valve rod 12. The valve rod 12 and inserted magnetized members 21 and 22 are arranged in a gap 33 located between yoke 32 and the magnetic poles 34,35 and 36 which are separate elements. Valve rod 12 is movable in both directions A and B, as shown in the figure. By moving the valve rod 12, the valve 11 may be moved to an opening position or closing position. Inside the gap 33, a magnetic field is formed in the regions of poles 34 and 35 and poles 35 and 36. Magnetized members 21 and 22 are arranged so that each member corresponds to each of the two magnetic field regions. In the central portion, the yoke 31 is formed around a core 37. Surrounding core 37 is a fixed frame 23 of nonmagnetic material such as resin. At a side wall portion of fixed frame 23, electromagnetic coil 38 is wound around core 37. A magnetic gap 39 is arranged between an upper end of core 37 and yoke 31. The electromagnetic coil 38 is connected to a current source not shown in the figure. The current source supplies a driving current to the electromagnetic coil 38. The polarity of the driving current corresponds to either the closing direction or the opening direction of the valve element 11.

[0013] The following description, the magnetized member 21 facing the yoke 31 has a magnetic polarity of N, and a magnetic polarity of S on the side, facing yoke 32, for example. The magnetized member 22 facing the yoke 31 has a magnetic polarity of S, and on the side facing yoke 32 has a magnetic polarity of N.

[0014] When current is not supplied to electromagnetic coil 38, the magnetic resistance of magnetic gap 39 is greater than the magnetic force of magnetized members 21 and 22. Therefore, magnetized members 21 and 22 and, therefore, the valve rod 12 are positioned to a predetermined position (referred to as reference position hereinafter). In the reference position, magnetic field paths are circumferentially formed in the following sequence: the N pole of magnetized member 21, magnetic pole member 34, yoke 31, magnetic pole member 36, the S pole of magnetized member 22, the N pole of magnetized member 22, yoke 32, and the S pole of magnetized member 21. A second sequence is: the N pole of magnetized member 21, magnetic pole member 35, the S pole of magnetized member 22, the N pole of magnetized member 22, yoke 32, and the S pole of magnetized member 21.

[0015] However, when current is supplied to electromagnetic coil 38, magnetic flux is generated inside core 37 and the magnetic flux is distributed inside yoke 31 to create a magnetic pole at each surface of poles 34, 35 and 36 and forms a magnetic field in the magnetic field region. The polarities of a magnetic dipole occurring at pole 34 and 36 are the same, whereas the polarity of the magnetic dipole occurring at pole 35 is of opposite polarity. For example, when direct current flowing in a predetermined direction is applied to electromagnetic coil 38, an S magnetic pole is created at poles

34 and 36, whereas an N magnetic pole is created at pole 35. When direct current flowing in the other direction is applied to electromagnetic coil 38, an N magnetic pole is created at poles 34 and 36, whereas an S magnetic pole is created at pole 35.

[0016] When an S magnetic pole is created at poles 34 and 36 and an N magnetic pole is created at pole 35, a new magnetic path is circumferentially formed in the following sequence: the N pole of magnetized member 21, magnetic pole member 34, yoke 31, magnetic gap 39, core 37, magnetic pole member 35, the S pole of magnetized member 22, the N pole of magnetized member 22, yoke 32, and the S pole of magnetized member 21 so as to move the magnetized members 21 and 22 together with valve rod 12 in the direction of arrow A, as shown in Figure 1. On the contrary, when an N p le is created at poles 34 and 36 and S pole is created at pole 35, a new magnetic path is circumferentially formed in the following sequence: the N pole of magnetized member 21, magnetic pole member 35, core 37, magnetic gap 39, yoke 31, magnetic pole member 36, the S pole of magnetized member 22, the N pole of magnetized member 22, yoke 32 and the S pole of magnetized member 21 so as to move the magnetized members 21 and 22 together with valve rod 12 in the direction of arrow B.

[0017] As mentioned above, when current is not supplied to electromagnetic coil 38, valve 11 may be positioned to a predetermined position and by changing the direction of the current supplied to electromagnetic coil 38, valve rod 12 may be moved to either direction A or B so as to position the valve 11 to one of the opened position or a closed position.

[0018] Figure 3 shows the relationship between the position of the magnetized members and the driving force applied to the magnetized members wherein the moving distance of the magnetized member is ± 4 millimeters, for example. This graph is obtained by applying a predetermined current (1 ampere to 15 ampere, f r example) to the electromagnetic coil of the actuator and detecting the driving force required to stop the magn tized members in a predetermined position e.g., -4 mm to +4 mm.

[0019] The magnitude of driving force applied to magnetized members decreases as the position of the magnetized members moves in the positive direction. When the valve apparatus is in any one of the predetermined positions, as the magnitude of the current applied to the electromagnetic coil increases, the amount of driving force applied to the valve apparatus increases. The position of the magnetized members, when the driving force is zero, is the reference position of the magnetized members.

[0020] The graph of Figure 3 shows the effect of direct current flowing in a predetermined direction applied to the electromagnetic coil. When the direct current flows in the opposite direction, then the driving force is reversed.

[0021] Driving force in a conventional apparatus as is disclosed in Japanese Patent No. 2,772,569 is in inverse proportion to the second power of the distance of the moving element, whereas the apparatus of the present invention, which is constructed as stated above, is abl to provide a stable driving force without relying on the position of the magnetized members which are movable.

[0022] Figure 4 shows the relationship between the time required to transfer or move the magnetized members and position of the magnetized member as well as the acceleration of the magnetized members derived from numerical computation. In this graph, the internal combustion engine rotates at high-speed, 6000 rpm for example, and the magnetized member are moved together with the valve member and the valve rod.

[0023] As shown in the upper portion of the graph of Figure 4, when driving force is applied to the magnetized members to drive the members, the transformation waveform acceleration is rectangularly shaped and the transformation waveform of displacement of the member is a curved line as shown in the lower portion of the graph of Figure 4. Moreover, in this case, when the maximum moving distance of the magnetized members is set to a predetermined value (8mm for example), the initial position of the magnetized members is -4mm movement in direction B and the maximum moving distance of the magnetized members is +4mm movement in direction A. Then, controlling the velocity of the magnetized members at the initial position and maximum movement position, respectively, to zero velocity may be achieved by altering the acceleration of the magnetized members from -230G to +230G as shown in the upper portion of the graph of Figure 4. As discussed above, valve 11 is integrally formed in one body by incorporating magnetized members 21, 22 and the valve rod 12, and the position where the magnetized members are located at the initial position corresponds to the valve closing position and the position where the magnetized members are positioned at the position of maximum movement corresponds to the valve opening position. In summary, in order to control the valve so that it does not collide with the valve seat as well as to position the valve at the valve closing and opening positions at a velocity of 0, by applying an acceleration to create a value of ±230G to the magnetized member (valve element), for example. As a result, the apparatus of the present invention reduces valve impact upon seating by use of a simple structure.

[0024] Figure 5 shows a cross section of the region of the combustion chamber of an internal combustion engine, wherein the valve driving apparatus shown in Figure 1 is applied to control the flow of intake gas and exhaust gas of the internal combustion. Components which correspond to components shown in Figure 1 are given the same reference numbers.

[0025] From the suction pipe 51 of internal combustion engine 50, air having a flow rate controlled by throt-

tle valve 57 is introduced to a combustion chamber intake. From the injector 52 located at the suction pipe 51, fuel is injected. Intake air and fuel is mixed in suction pipe 51 to become air-fuel mixture. A crank angle sensor is arranged adjacent to the crank shaft (not shown) so that when the crank angle reaches a predetermined angle, a position signal pulse is transmitted. When the position signal pulse to initiate the intake stroke is transmitted from the crank angle sensor, current is supplied to actuator 30 to move the valve rod 12 inwardly in the direction of combustion chamber 53 together with the magnetized members 21 and 22 and to open the valve 11 to let the air-fuel mixture into the combustion chamber 53. Subsequently, when the position signal pulse to initiate the compression stroke is transmitted from the crank angle sensor, current in an opposite direction to the current applied at intake is applied to actuator 30 to move the valve rod 12 in the opposite direction to close the valve 11. When the position signal pulse to initiate the combustion stroke is transmitted, ignition plug 54 is ignited and air-fuel mixture in the combustion chamber 53 is combusted. This combustion increases the volume of air-fuel mixture and moves the piston 55 downward. This piston 55 motion is transmitted to the crank shaft and is converted to rotational motion of the crank shaft. When the position signal pulse to initiate the exhaust stroke is transmitted, current is supplied to actuator 30' and valve rod 12' moves inwardly of combustion chamber 53 together with the magnetized members 21' and 22' and opens the valve 11' to exhaust the combusted air-fuel mixture gas to exhaust pipe 56 as exhaust gas. Subsequently, when the position signal pulse to initiate the intake stroke is transmitted, valve 11' closes and the intake stroke of the next cycle begins.

[0026] Between the intake pipe 51 and exhaust-pipe 56 of the internal combustion engine 50, a re-circulation pipe 58 is arranged to connected the intake and exhaust pipes. The re-circulation pipe 58 is arranged with exhaust gas re-circulation system 131 (hereinafter referred as EGR system) to control exhaust gas flow. Exhaust gas exhausted from internal combustion engine 50 is supplied to intake pipe 51 by flowing through the re-circulation pipe 58 and has its flow rate controlled by the EGR system 131. The EGR system 131 comprises the valve driving apparatus shown in Figure 1, i.e., a valve 11", a valve rod 12", magnetized members 21" and 22", and an actuator 30". Thus, the valve driving apparatus controls the flow of the exhaust-gas supplied to intake pipe 51.

[0027] Further, intake pipe 51 of the internal combustion engine 50 has a by-pass pipe 59 which detours around the air supplied upstream of the intake pipe 51 and supplies the air to the downstream side of the intake pipe 51. The by-pass pipe 59 is equipped with an idle speed control unit 132 (hereinafter referred as ISC system) to control the air flow rate supplied to the internal combustion engine 50. The ISC system comprises a valve driving apparatus shown in Figure 1, i.e., a valve 11"', a valve rod 12"', magnetized members 21"' and 22"', and an actuator 30"'. Thus, the valve driving apparatus controls the air flow rat supplied to the internal combustion engine 50.

[0028] Intake gas supplied to internal combustion engine 50 comprises air supplied to intake pipe 51 and air supplied through th ISC system 132 to the downstream side of intake pipe 51 as mentioned above, while exhaust gas exhausted from the internal combustion engine 50 comprises exhaust-gas exhausted from the internal combustion engine 50 and exhaust-gas supplied to the EGR system.

[0029] The valve driving apparatus applied to the internal combustion engine shown in Figure 5 is not limited to the valve driving apparatus of the first embodiment shown in Figure 1, for example, the second to sixth embodiments of the valve driving apparatus to be discussed later may also be applied.

[0030] Figure 6 shows the valve driving apparatus of the second embodiment of the present invention. Components which correspond to components shown in Figure 1 are given the same reference numbers.

[0031] A hole sensor 41 is arranged in magnetic gap 39 and detects flux density which passes through the magnetic gap 39. A voltage signal which corresponds to the detected magnetic flux density is transmitted from hole sensor 41 and the voltage signal is supplied to a position detecting signal processor (not shown). As mentioned above, the position of magnetized members 21 and 22 is determined according to the magnitude of generated flux density in core 37 or flux density which passes through the magnetic gap 39 and therefore, by detecting flux density, the position of magnetized members 21 and 22 may be obtained. By providing driving current to electromagnetic coil 38 corresponding to the position of magnetized members 21 and 22, valve 11 may be controlled accurately.

[0032] Figure 7 shows the valve driving apparatus of the third embodiment of the present invention. Components which correspond to components shown in Figures 1 and 6 are numbered in the same manner.

[0033] Electromagnetic coil 42 is wound at the upper end of core 37 and detects transformation of the magnetic flux generated in core 37 and outputs a voltage signal which corresponds to the detected magnetic flux to be supplied to a velocity detecting signal processor (not shown). Since magnetic flux generated in core 37 changes according to the velocity of the magnetized member, by detecting the transformation of flux density, velocity of the magnetized members 21 and 22 may be obtained so as to allow precise control of the valve 11 by supplying driving current corresponding to the velocity of the members 21 and 22 to the electromagnetic coil 38.

[0034] Figure 8 shows the valve driving apparatus of the fourth embodiment of the present invention. Components which correspond to components shown in Figures 1, 6 and 7 are given the same reference numbers.

[0035] Magnetic gap 39 is arranged at yoke 31 in a position offset to the side of pole 34 with respect to the center line C of the core 37. Magnetic gap 40 is arranged in the lower part of pole 34. As will be described lat r, when current is not supplied to electromagnetic coil 38, valve rod 12 is l cat d below pole 34 so that the magnetic gap 40 is identified as a gap formed between pole 34 and valve rod 12. To the contrary, when current is supplied to electromagnetic coil 38, valve rod 12 moves in the direction of arrow A, shown in the figure, together with magnetized members 21 and 22 to place the magnetized member 21 underneath pole 34 so that magnetic gap 40 is identified as a gap formed between pole 34 and magnetized member 21. Pole element 34 is formed so that the dimension of the gap along the overall length direction of the valve rod is constant.

[0036] In this valve driving apparatus, when current is not supplied to electromagnetic coil 38, magnetic resistance of magnetic gaps 39 and 40 is greater than the magnetic force of magnetized members 21 and 22. Therefore, magnetized members 21 and 22 are positioned to a predetermined position offset in the direction B, in the figure, together with valve rod 12, so that a magnetic path is circumferentially formed in the following sequence: the N pole of magnetized member 21, magnetic pole member 35, core 37, yoke 31, magnetic pole member 36, the S pole of magnetized member 22, the N pole of magnetized member 22, yoke 32, and S pole of magnetized member 21. In the case of the valve driving apparatus shown in Figure 8, this position becomes a reference position and when current is not supplied to electromagnetic coil 38, valve rod 12 is always set to this reference position.

[0037] However, when current is supplied to electromagnetic coil 38, magnetic flux passes through both gaps 39 and 40. Therefore, magnetized members 21 and 22 move in the direction A, shown in the figure, together with valve rod 12, so that a magnetic path is circumferentially formed in the following sequence: the N p le of magnetized member 21, magnetic gap 40, pole member 34, yoke 31, magnetic gap 39, yoke 31, core 37, magnetic pole member 35, the S pole of magnetized member 22, the N pole of magnetized member 22, yoke 32, and the S pole of magnetized member 21. A second sequence is: the N pole of magnetized member 21, magnetic gap 40, pole member 34, yoke 31, magnetic gap 39, yoke 31, magnetic pole member 36, the S pole of magnetized member 22, the N pole of magnetized member 22, yoke 32, and the S pole of magnetized member 21.

[0038] Further, when current supplied to electromagnetic coil 38 is increased, magnetized members 21 and 22 move in the direction A in the figure, together with valve rod 12, so that a magnetic path is circumferentially formed solely in the sequence of the N pole of magnetiz d member 21, magnetic gap 40, pole member 34, yoke 31, magnetic gap 39, yoke 31, core 37, magnetic pole member 35, the S pole of magnetized member 22, the N pole of magnetized member 22, yoke 32, and the S pole of magnetized member 21.

[0039] As mentioned above, in the valve driving apparatus shown in Figure 8, when current is not supplied to electromagnetic coil 38, valve rod 12 is always set to a predetermined position offset in the direction of arrow B as a reference position. However, where magnetic gap 39 is arranged at yoke 31 in a position offset to the pole 36 side from the central line of the core 37 and the magnetic gap 40 is arranged in the lower part of pole 36, when current is not supplied to electromagnetic coil 38, valve rod 12 is always set to a predetermined position offset in the direction d arrow A as reference position. By changing the location of magnetic gaps 39 and 40, one may select the reference position to be either a position offset in the direction of arrow A (valve open position, for example) or a position offset in the direction of arrow B (valve close position, for example).

[0040] When varying the gap size of magnetic gaps 39 and 40, the magnitude of magnetic resistance of magnetic gaps 39 and 40 also varies. Furthermore, the magnitude of magnetic resistance of magnetic gap 40 changes as magnetized members 21 and 22 move with valve rod 12. Therefore, when magnetic gaps 39 and 40 are changed, even when the magnitude of the current supplied to electromagnetic coil 38 is the same, the formed flux density of the magnetic flux and transformation of the flux density varies. This enables one to establish the required driving force magnitude or driving force transformation rate of the valve rod 12 and magnetized members 21 and 22.

[0041] In the aforesaid embodiment, among the plurality of poles positioned in parallel along the lengthwise direction of the valve rod, an example is shown wherein a magnetic gap 40 is arranged at the lower portion of the extreme outer side pole. However, the magnetic gap may be arranged at location of any of the other poles. Also, the magnetic gap dimension (the gap dimension between the valve rod and the pole or gap dimension between the magnetized member and the pole) of the disclosed embodiment is substantially uniform along the lengthwise direction of the valve rod, but the gap may be configured to vary.

[0042] Figure 9 shows the valve driving apparatus of the fifth embodiment of the present invention. Components which correspond to components shown in Figures 1, 6, 7 and 8 are given the same reference numbers.

[0043] Yoke 71 of actuator 70 is configured to be U shaped and at the inner wall of the leg of the yoke 71, two poles 72 and 73 are set facing each other. Valve rod 15, having a rectangular cross section is arranged at gap 74 of poles 72 and 73 so that it may slide along the lengthwise direction. In like manner as the valve rod 12 shown in Figure 2, in the through hole (not shown) arranged in valve rod 15, a magnetic pole is provided such that the N pole of magnetized member 21 faces

pole 72 and the S pole of magnetized member 21 faces pole 73. In the gap 74, a magnetic field region is formed in the neighborhood of poles 72 and 73 and magnetized member 21 is arranged to correspond with the magnetic field region. Surrounding the trunk of yoke 71, there is arranged a fixed frame 23 comprising nonmagnetic material such as resin. Along the side wall portion of fixed frame 23, there is wound electromagnetic coil 38 to surround the trunk of yoke 71. Electromagnetic coil 38 is connected to current source which is not shown and the current source supplies driving current to the electromagnetic coil 38 wherein the polarity of the current corresponds to either the valve closing direction or the valve opening direction of valve 11. Furthermore, yokes 75 and 76 which are additional magnetic path members are arranged to sandwich valve rod 15. The N pole of magnetized member 21 faces yoke 75 and the S pole of magnetized member 21 faces yoke 76. As shown in Figure 10, the cross sections of both yokes 75 and 76 are configured to be U-shaped and leg portions of yoke 75 and 76 are arranged so that they are opposed to each other. Also, between the legs of yoke 75 and 76, magnetic gaps 77 and 78 are arranged.

[0044] When current is not supplied to electromagnetic coil 38, magnetized member 21 is positioned to a predetermined position together with valve rod 15, so that a magnetic path is circumferentially formed in the following sequence: the N pole of magnetized member 21, magnetic pole member 72, yoke 71, magnetic pole member 73 and the S pole of magnetized member 21.

[0045] When current is supplied to electromagnetic coil 38, magnetic flux is generated in yoke 71 and a magnetic dipole is generated on the surface of both magnetic pole members 72 and 73. For example, when direct current in a predetermined direction is supplied to electromagnetic coil 38, a pole of N polarity is created at magnetic pole member 72 and a pole of S polarity is created at magnetic pole member 73. When direct current in a direction opposed to the predetermined direction is supplied to electromagnetic coil 38, the S polarity pole is created at magnetic pole member 72 and the N polarity pole is created at magnetic pole member 73.

[0046] In the case where the N pole is created at magnetic pole member 72 and the S pole is created at magnetic pole member 73, as shown by two dotted line arrows in Figure 10, new magnetic paths are circumferentially formed in the following sequence: the N pole of magnetized member 21, yoke 75, magnetic gap 77, yoke 76, the S pole of magnetized member 21. A second sequence is: the N pole of magnetized member 21, yoke 75, magnetic gap 78, yoke 76 and the S pole of magnetized member 21 so that magnetized member 21 moves in the direction of arrow A, shown in Figures 9 and 10 together with the valve rod 15 according to the magnitude of the magnetic flux density generated in yoke 71. To the contrary, when the S pole is created at magnetic pole member 72 and the N pole is created at magnetic pole member 73, the two magnetic paths are extinguished so that magnetized member 21 moves to the direction of arrow B together with the valve rod 15 according to the magnitude of the magnetic flux density generated in yoke 71.

[0047] Figures 11 and 12 show the valve driving apparatus of the sixth embodiment of the present invention. Components which correspond to components shown in Figures 1, 6, 7, 8 and 9 are given the same reference numbers. Also, Figure 12 shows the valve driving apparatus shown in Figure 11 in which upper frames 81 and 81', lower frame 88 and coil 38 are omitted.

[0048] Upper frame 81 which is the second supporting member is configured in a U-shape form with top portion 82 and two legs 83 and in the middle of the legs 83 is a bracket member 84 connecting the two legs. Upper frame 81' also has a structure similar to upper frame 81.

[0049] The upper frames 81 and 81' have supporting protrusions (not shown) which support yoke 31 and the yoke 31 is provided with supporting holes (not shown) which correspond to the supporting protrusions. By coupling the supporting protrusions and supporting holes the frame is assembled and yoke 31 can be held in a predetermined position between the upper frames 81 and 81'. Also, when upper frames 81 and 81' are assembled to the yoke 31, the winding 38 which is wound around core 37 inside the yoke 31 is placed inside the opening formed by the top portions of upper frames 81 and 81' ,leg portions 83 and bracket member 84.

[0050] As will, be discussed later, moving element 91 which is a supporting body of a magnetized member is arranged between poles 34 and 36 of yoke 31 and pole 35 of core 37 to provide a gap as shown in Figure 12. Furthermore, the moving element 91 is arranged to also form a gap between the yoke 32 which is an independent magnetic path member. These gaps are retained by rollers 101 and 102, and 103 and 104 (not shown). At an end of moving element 91, lock member 92 is provided. As mentioned later, lock member 92 has a locking hole 93 and a valve rod supporting groove 94. At an end of valve rod 12, there is an enlarged diameter portion 16 which is fit into the locking hole 93. Valve rod 12 has a valve element 11. By supplying current to coil 38 to operate the moving element, valve element 11 may be moved in the direction of arrow A (valve opening direction, for example) or in the direction of arrow B (valve closing direction, for example), as shown in the figure.

[0051] As shown in Figure 14, to be discussed later, lower frames 88 and 88' which are the first holding member ,have supporting protrusions to support yoke 32 and yoke 32 is arranged with supporting holes (not shown in the figure) in positions corresponding to the supporting protrusions. By coupling supporting protrusions and supporting holes thereby assembling the frame, yoke 32 can be held in a predetermined position between the lower frames 88 and 88'. Lower frames 88

and 88' are arranged such that the length in the lengthwise direction is about the same as the distance between the legs 83 or 83' of the upper frames 81 or 81'. In the above structure, as shown in Figure 11, by arranging the lower frame 88 between the two legs 83 of upper frame 81 and the lower frame 88' between the two legs 83' of upper frame 81', yoke 32 may be positioned such that it does not move in neither the valve opening direction nor the valve closing direction.

[0052] The upper frames 81 and 81' which are the second holding member may have support holes (not shown) to fasten the valve driving apparatus to a predetermined location of an internal combustion engine.

[0053] Figure 13 shows the upper frame viewed from below. Components which correspond to components shown in Figures 11 and 12 are given the same reference numbers.

[0054] As discussed above, the upper frame 81 has a bracket member 84 which connects the two leg 83. At the underneath surface of this bracket member 84, guide grooves 85 and 86 are formed so that the movement of the second locking members, that is, rollers 103 and 104 (not shown in the figure) are guided, respectively, as will be discussed later. This guide groove, as the second guide groove, has a rectangular aperture and its sectional configuration is also rectangular. Since this guide groove is formed underneath the bracket member 84, when the frame is assembled to form a valve driving apparatus as shown in Figure 11, the guiding groove faces the moving element 91. Furthermore, roll rs 103 and 104 roll freely in the guide grooves 85 and 86 in their lengthwise direction to form a width dimension of the guide grooves substantially identical to the overall length of the roller. The guide groove is formed so that the dimension of the depth of the guide groove is less than the diameter of the roller. Furthermor , the guide groove is formed such that the overall length of the guide groove corresponds to the moving distance of the moving element. The upper frame 81', of Figure 13, is also structured in a same manner as the upp r frame 81.

[0055] Figure 14 shows yoke 32 which is supported between lower frames 88 and 88'. Components which correspond to components shown in Figures 11 and 12 are numbered in the same manner.

[0056] The lower frame 88 which is the first supporting member is supported between two legs 83 of the upper frame 81 such that dimension of the lower frame 88 in the lengthwise direction is substantially equal to the distance between the two legs 83. On the top surface of the lower frame 88, the first guide grooves 89 and 90 are formed. The configuration of these guide grooves 89 and 90 are substantially equal to that of guid grooves 85 and 86. Rollers 101 and 102, as the first engaging member (not shown) may roll freely in the lengthwise direction of the guide grooves 89 and 90. The lower frame 88' is also structured in the same manner as the lower frame 88 and guide grooves 89 'and 90' are formed in its upper surface.

[0057] Figure 15 shows the magnetized members and the moving element. Components which correspond to components shown in Figures 11 and 12 are given the same reference numbers.

[0058] The moving lement 91 supports the magnetic members, and two magnetized members 21 and 22, e.g., permanent magnets, are inserted and fixed in the moving element so that the top and the bottom surfaces of the magnetized members align with the top and the bottom surfaces of the moving element 91. On the sides of moving element 91, protrusion 95 and 95' are arranged to protrude in the direction lateral to the length of the moving element 91. At the underneath surface of protrusions 95, lower engaging surfaces 96 are provided which respectively engage with rollers 101 and 102 (not shown) whereas at the upper surfaces of protrusion 95, upper engaging surfaces 98 are provided which respectively engage with rollers 103 and 104 (not shown). Further, underneath the protrusion 95 and at the lateral side of moving element 91, there is arranged an engaging surface 97 to engage with the circular end of rollers 101 and 102, and upward the protrusion 95 and at the side of moving element 91, there is arranged an engaging surface 99 to engage with the circular end of rollers 103 and 104. With regard to protrusion 95', lower engaging surface 96' (not shown), upper engaging surface 98', engaging surface 97', engaging surface 99' (not shown) are also arranged in a same manner as protrusion 95.

[0059] Figure 16 is a perspective view which shows the state of the rollers engaging with guide grooves and the protrusion of the lower frame. Figure 17 is a sectional view along line X-X, shown in Figure 11. Figure 18 is sectional view along line Y-Y, shown in Figure 11. Components which correspond to components shown in Figures 11, 14 and 15 are given the same reference numbers.

[0060] Each of the rollers 101 and 102 which are the first engaging members and each of the rollers 103 and 104 which are the second engaging members are cylindrically configured and have a barrel shape surface and two circular end surfaces. In the following description, a circular end surface faces engaging side face 97 or 99 of the moving element 91 at the inner end surface, and a circular end surface faces in a direction opposed to the engaging side face 97 or 99 at the outer end surface.

[0061] Referring to Figures 16 and 17, the roller 101 is arranged in guide groove 89 of the lower frame 88 , roller 102 is arranged in guide groove 90 of the lower frame 88, roller 103 is arranged in guide groove 85 of upper frame 81 and roller 104 is arranged in guide groove 86 of upper frame 81. As discussed above, the guide groove is formed so that the width of the groove is substantially equal to the length of the rollers, and by employing such a configuration, when the rollers rotate in the guide groove, the inner end surface and the outer

end surface engages with the guide groove sidewall surfaces, respectively, as shown in Figure 18, allowing the roller to move only in the lengthwise direction f the guide groove. As shown in Figures 16, 17 and 18, moving element 91 is arranged such that lower engaging surface 96 of the moving element 91 is capable of engaging with the barrel surface of rollers 101 and 102. Engaging side face 97 of the moving element 91 is capable of engaging with the inner end surfaces of rollers 101 and 102. Furthermore, moving element 91 is arranged such that upper engaging surface 98 of the moving element 91 is capable of engaging with the barrel surface of rollers 103 and 104. Engaging side face 99 of the moving element 91 is capable of engaging with the inner end surfaces of rollers 103 and 104.

[0062] As shown in Figure 18, guide groves 85', 86' ,89' and 90' are also configured in the same manner. Rollers 101', 102', 103' and 104' are also configured in the same manner as rollers 101 to 10. Finally, engaging side faces 97' or 99', lower engaging surface 96' and upper engaging surface 98' are configured in the same manner as the abovementioned counterparts.

[0063] By employing the abovementioned configuration, when current is applied to the electromagnetic coil shown in Figure 11 and forms a circumferential magnetic path in the following sequence: core 37, yoke 31, magnetized members 21 and 22, and yoke 32 to move the moving element 91, then as shown in Figure 18, engaging side face 97 of the moving element 91 engages with the inner end surfaces of rollers 101 and 102, engaging side face 99 of the moving element 91 engages with the inner end surfaces of rollers 103 and 104, engaging side face 97' of the moving element 91 engages with the inner end surfaces of rollers 101' and 102' and engaging side face 99' of the moving element 91 engages with the inner end surfaces of rollers 103' and 104' to slide the moving element 91.

[0064] By employing the configuration shown in Figures 16, 17 and 18, every roller moves with the guidance of the guide grooves and the moving element 91 slides with the guidance of each of inner end surfaces of rollers.

[0065] The rollers 101 to 104 and 101' to 104' allow smooth movement of the moving element 91 in the desired direction. As shown in Figure 17, these rollers also function to determine the distance between the moving element 91 and upper frames 81 and 81' as well as between the moving element 91 and lower frames 88 and 88'. Furthermore, as discussed above, upper frames 81 and 81' support the yoke 21 and the core 37 and lower frames 88 and 88' support the yoke 32 so that rollers 101 to 104 and 101' to 104' determine the gap between magnetized members 21 and 22 and magnetic poles 34, 35 and 36 as well as the gap between magnetized members 21 and 22 and the yoke 32.

[0066] Magnetic force generated from the magnetic flux of magnetized members 21 and 22 draws the magnetized members 21 and 22 in the direction of yoke 21 and core 37 and also draws yoke 32 in the direction of the magnetized members 21 and 22. Due to this magnetic force, as shown in Figure 11 where the lower frame 88 is arranged between two legs 83 of the upper frame 81 and lower frame 88' is arranged between two legs 83' of the upper frame 81', no supporting member is required to hold the yoke 32 towards the yoke 31 (in the upper direction in Figure 11) and yoke 32 and lower frame 88 and 88' may be supported towards the yoke 31.

[0067] In the foregoing embodiment, cylindrical, rollers 101 to 104 and 101' to 104' were characterized as the first engaging member and the second engaging member. However, as shown in Figure 19, spheroid elements 111 to 114 may be provided. In this case, by configuring the cross sections of first guide groove 121 and 122 and the second guide groove (not shown) to a V shape, spheroid elements 111 to 114 may be securely engaged to the first guide groove and the second guide groove.

[0068] Figure 20 shows a lock member of the moving element and a valve element.

[0069] Valve head 11 of the valve element 10 is circular when viewed from the front and the valve head 11 is connected to the end of the valve rod 12 to form a uniform member. At the other end of the valve rod 12, there is an enlarged diameter element 16 having a diameter greater than the valve rod 12.

[0070] Referring to lock member 92 fixed at the moving element 91, a locking hole 93 is formed with a rectangular aperture and a rectangular sectional configuration. In a front portion of the lock member 92, there is a supporting groove 94 having a U-shaped cross section, viewed from the surface of the lock member 92 towards the locking hole 93.

[0071] When inserting the enlarged diameter portion 16 into the locking hole 93 to assemble the valve element 10 to the moving element 91, the side face of locking hole 93 engages with the barrel surface and circular end surface of the enlarged diameter portion 16 and the support groove engages with the barrel surface of the valve rod 12 to support the valve element 10 to the lock member 92. By employing such a structure, valve element 10 may be easily and accurately installed to the moving element 91. Furthermore, when locking hole 93 is designed according to the configuration of the conventional valve element, the conventional valve element may be assembled to the valve driving apparatus disclosed in the sixth embodiment without adding any modification to the valve element.

[0072] In the foregoing embodiment, the end portion of valve rod 12 is shown as having an enlarged diameter portion 16 of cylinder shape, but the end portion may be formed differently, such as a spherical body. Also, the aperture configuration of the locking hole 93 may be another polygonal shape other than rectangular.

[0073] As described above, the valve driving apparatus according to the present invention allows to sim-

plify the configuration of the apparatus, reducing valve seating impact and precisely controlling the valve element.

Claims

1. A valve driving apparatus for driving a valve element controlling intake gas flow or exhaust gas flow of an internal combustion engine which is characterized by:

   driving means including a magnetized path member comprising a magnetic flux generating element in which an electromagnetic coil is wound to generates magnetic flux and a magnetic field generating element comprising at least two pole members to distribute said magnetic flux to form at least one magnetic field,
   a magnetizing member moving within said magnetic field in cooperation with a valve rod formed integrally with said valve element, said member having two magnetized surfaces with mutually different polarities,
   current supply means for supplying a driving current to said electromagnetic coil corresponding to the poles of either a valve opening direction or a valve closing direction of said valve element.

2. A valve driving apparatus according to claim 1, wherein said magnetic path member comprises a gap in the path formed between said magnetic flux generating element and said pole members or at said magnetic flux generating element.

3. A valve driving apparatus according to claim 2, wherein said current supply means comprises a control means, said control means arranged at said magnetic gap to detect the magnetic flux density inside said magnetic gap to control said driving current according to said magnetic flux density.

4. A valve driving apparatus according to claim 1, wherein said current supply means is provided at the magnetic flux generating element to detect magnetic flux density transformation inside said magnetic flux generating element, said current supply means further comprising control means to control said driving current according to said magnetic flux density transformation.

5. A valve driving apparatus according to claim 1, wherein said pole members comprise three members mutually aligned in a lengthwise direction of said valve rod.

6. A valve driving apparatus according to claim 5, wherein a gap dimension formed between at least one of said pole members and said magnetized member is different from a gap dimension formed between other pole members and said magnetized member.

7. A valve driving apparatus according to claim 1, wherein said driving means interpose said magnetized member with said pole member and said driving means includes a separate magnetized path member independent from said magnetized member.

8. A valve driving apparatus according to claim 1, wherein said driving means comprises a separate magnetized member provided adjacent said magnetized member to surround said valve rod and includes a magnetized gap to increase the magnetic resistance of a magnetized closed path formed around said valve rod.

9. A valve driving apparatus according to claim 7 comprising;

   a support member supporting said magnetized member,
   support means supporting said separate magnetized member to a predetermined position to avoid movement in said valve opening direction and said valve closing direction.
   engaging means engaging with said support member and said support means to provide a gap in-between said magnetized member and said magnetic path member and in-between said magnetized member and said separate magnetic path member and to guide said support member freely for movement in both said valve closing direction and said valve opening direction.

10. A valve driving apparatus according to claim 9 wherein said support means comprises a first support member to support said separate magnetic member, and a second support member with a support portion to support said first support member in a interposed manner and to support said separate magnetic member.

11. A valve driving apparatus according to claim 10 characterized;

   in that said engaging means comprises a first engaging member which engages said support member and said first support member to guide said support member, and a second engaging member which engages said support member and said second support member to guide said support member,
   in that said first engaging member is arranged

in line with said valve opening direction and said valve closing direction to face said opposing support member and to engage with said first engaging member to guide said first engaging member, and

in that said second engaging member is arranged in line with said valve opening direction and said valve closing direction to face said opposing support member and to engage with said second engaging member to guide said second engaging member.

12. A valve driving apparatus according to claim 9 comprising: locking means removably supporting said valve rod and said support member.

13. A valve driving apparatus according to claim 12 wherein said locking means comprises;

an enlarged diameter portion at an end of said valve rod having a diameter greater than a diameter of said valve rod,
a locking hole formed in said supporting member to support said enlarged diameter portion when said valve rod is positioned in said support member, and
a supporting groove extending from a surface of said support member to said locking hole to support said valve rod.

FIG. 1

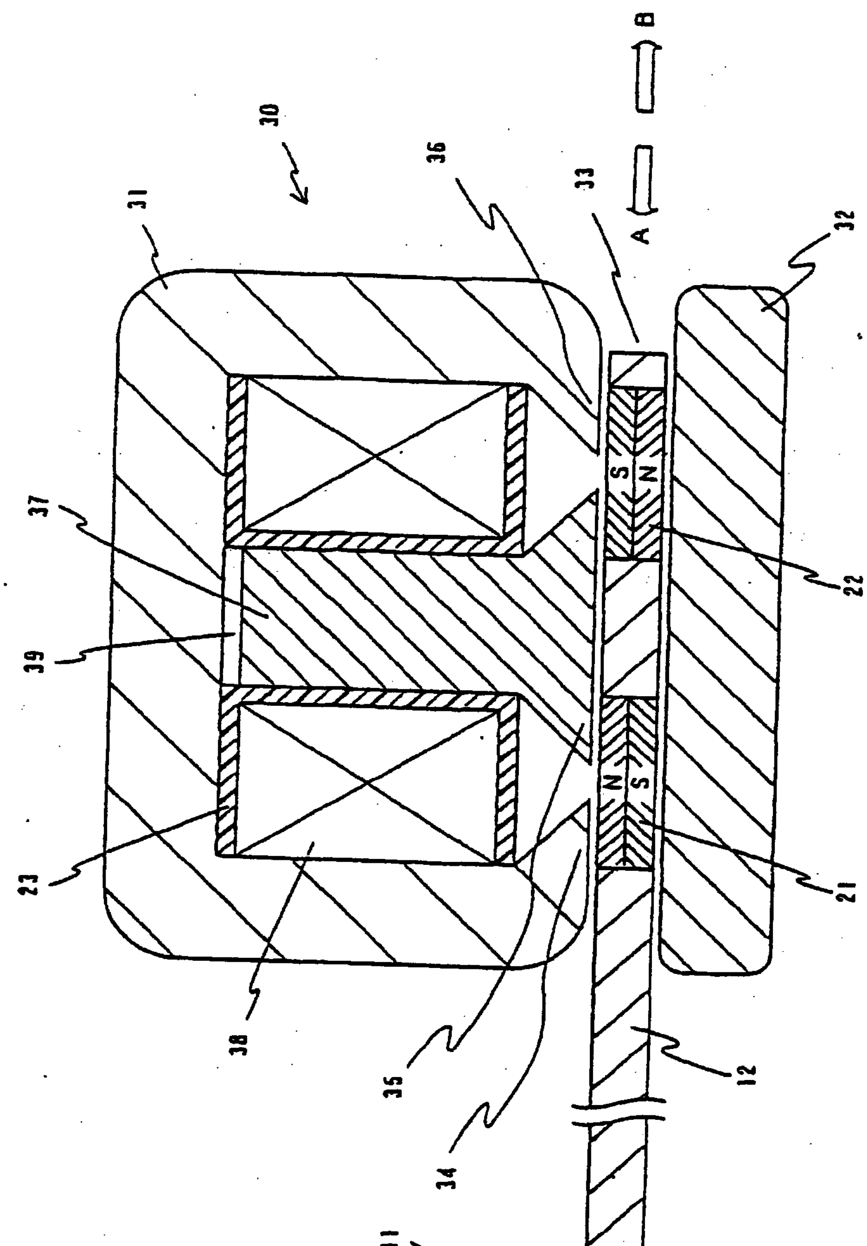


FIG. 2

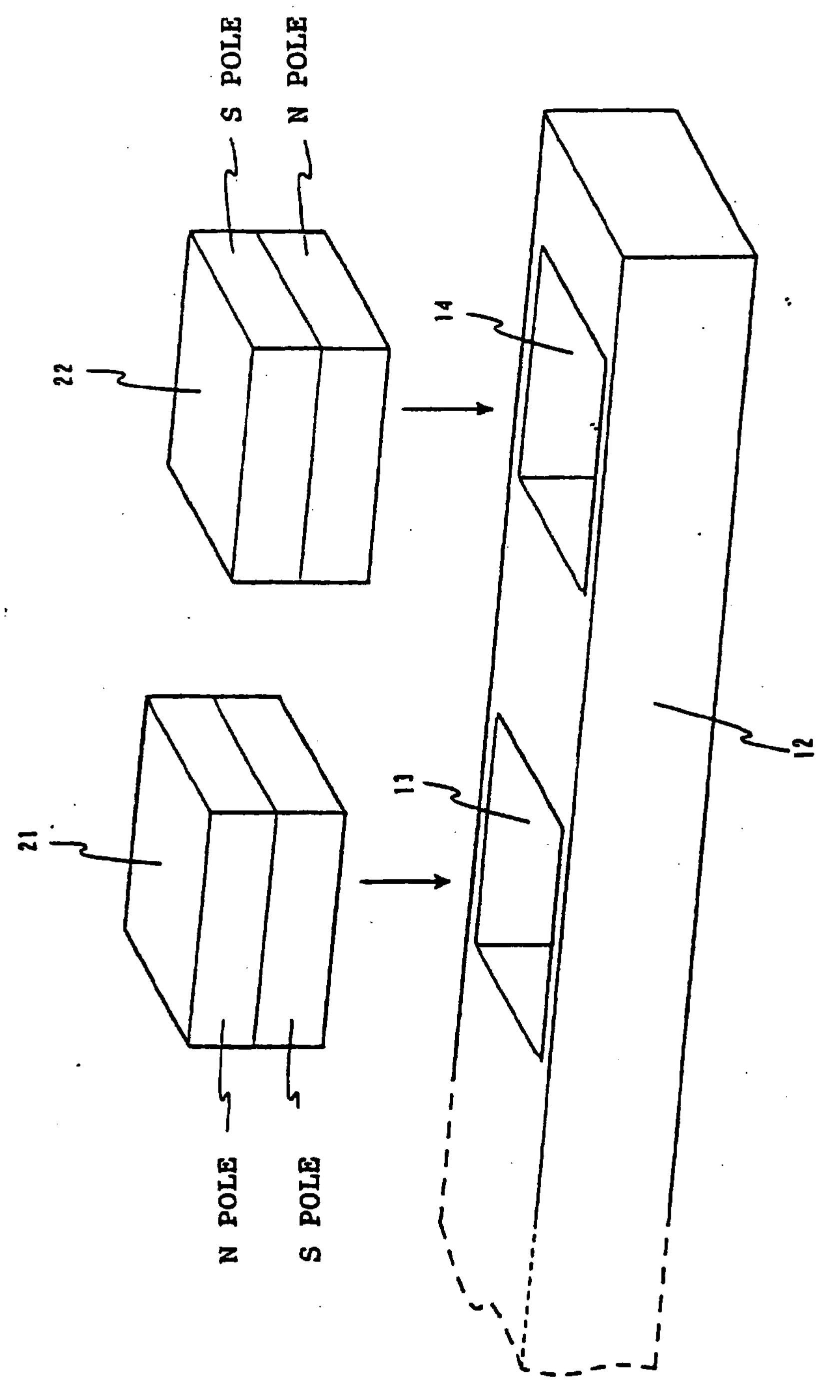
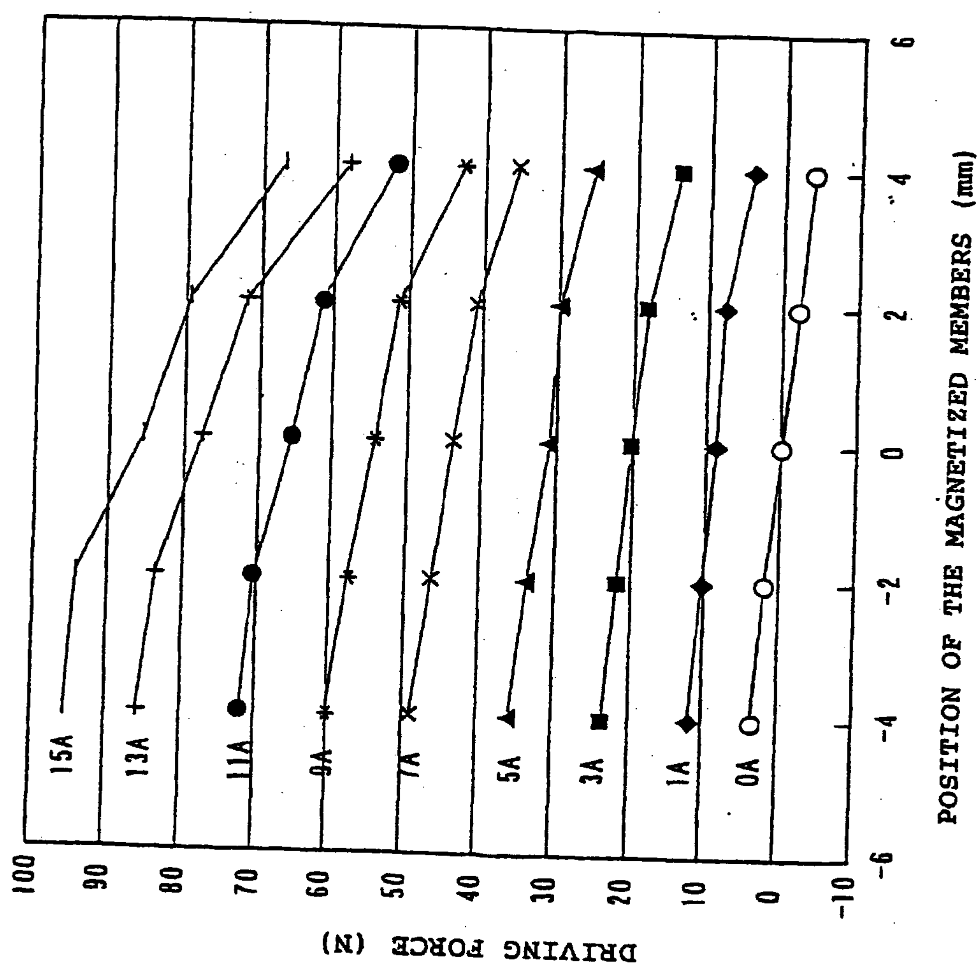


FIG. 3


DRIVING FORCE (N)
POSITION OF THE MAGNETIZED MEMBERS (mm)
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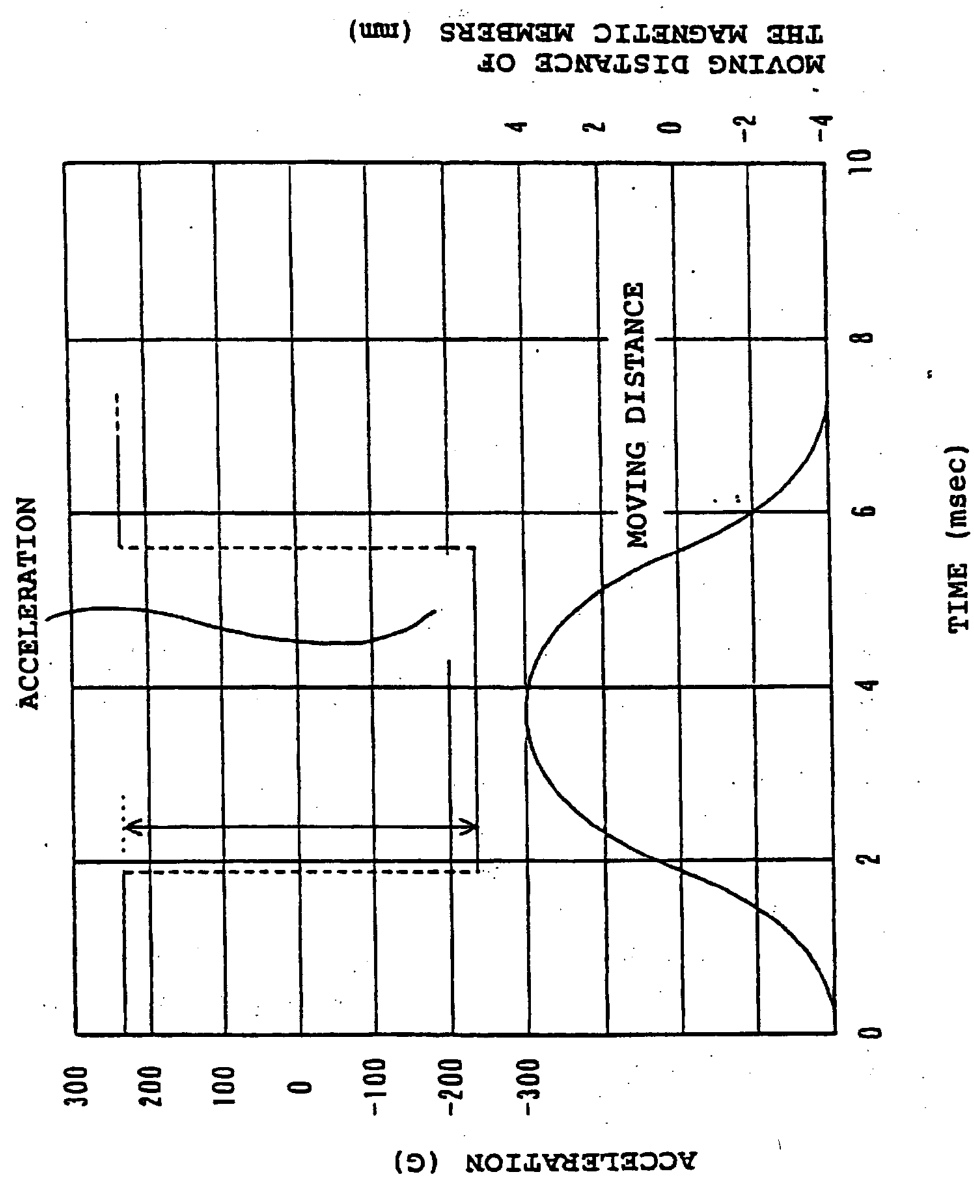
90
80
70
60
50
40
30
20
10
0
-10
-6
-4
-2
0
2
4
6
15A
13A
11A
9A
7A
5A
3A
1A
0A

FIG. 4


ACCELERATION
MOVING DISTANCE
ACCELERATION (G)
300
200
100
0
-100
-200
-300
MOVING DISTANCE OF THE MAGNETIC MEMBERS (mm)
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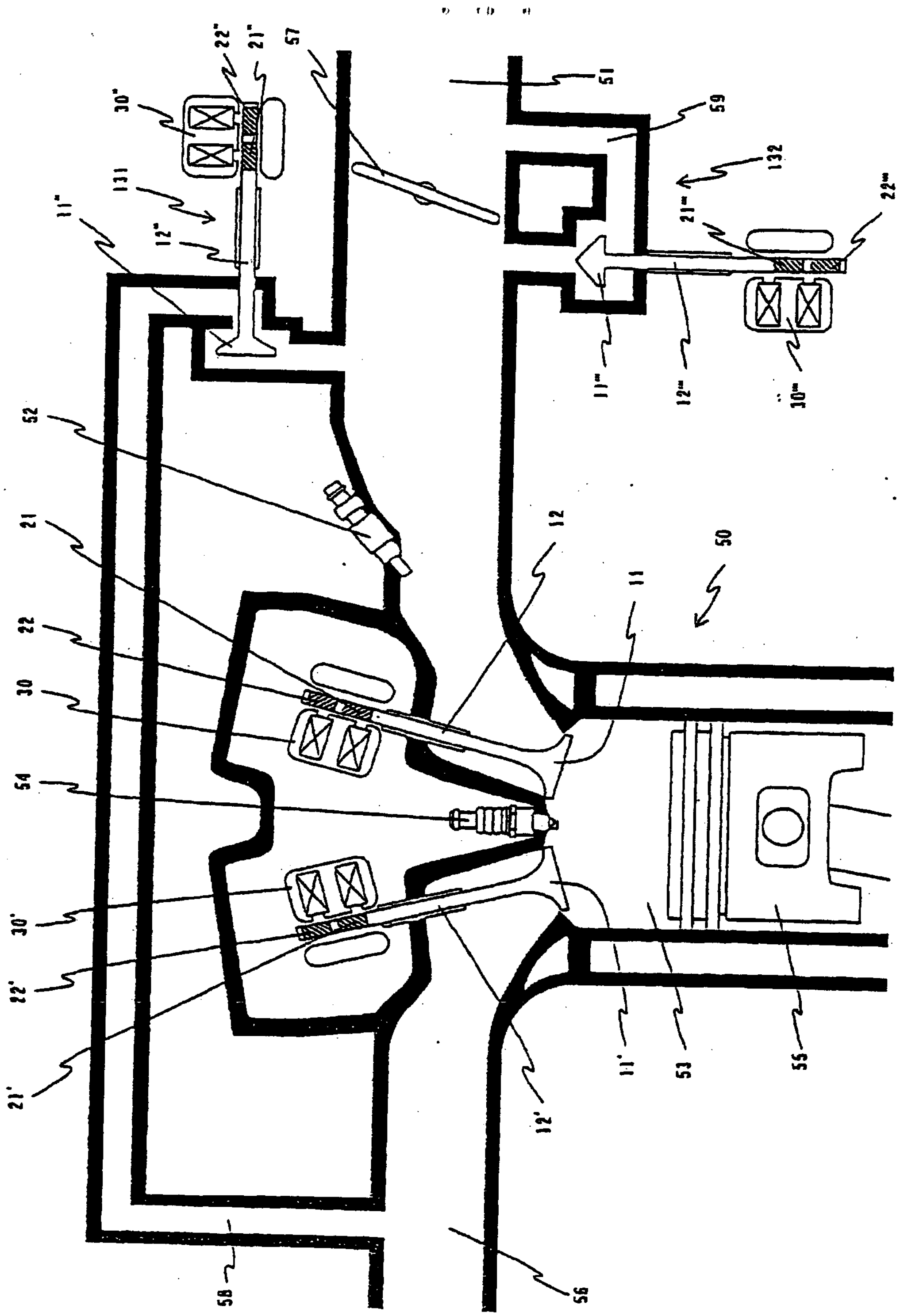
2
0
-2
-4
TIME (msec)
0
2
4
6
8
10

FIG. 5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56

FIG. 6

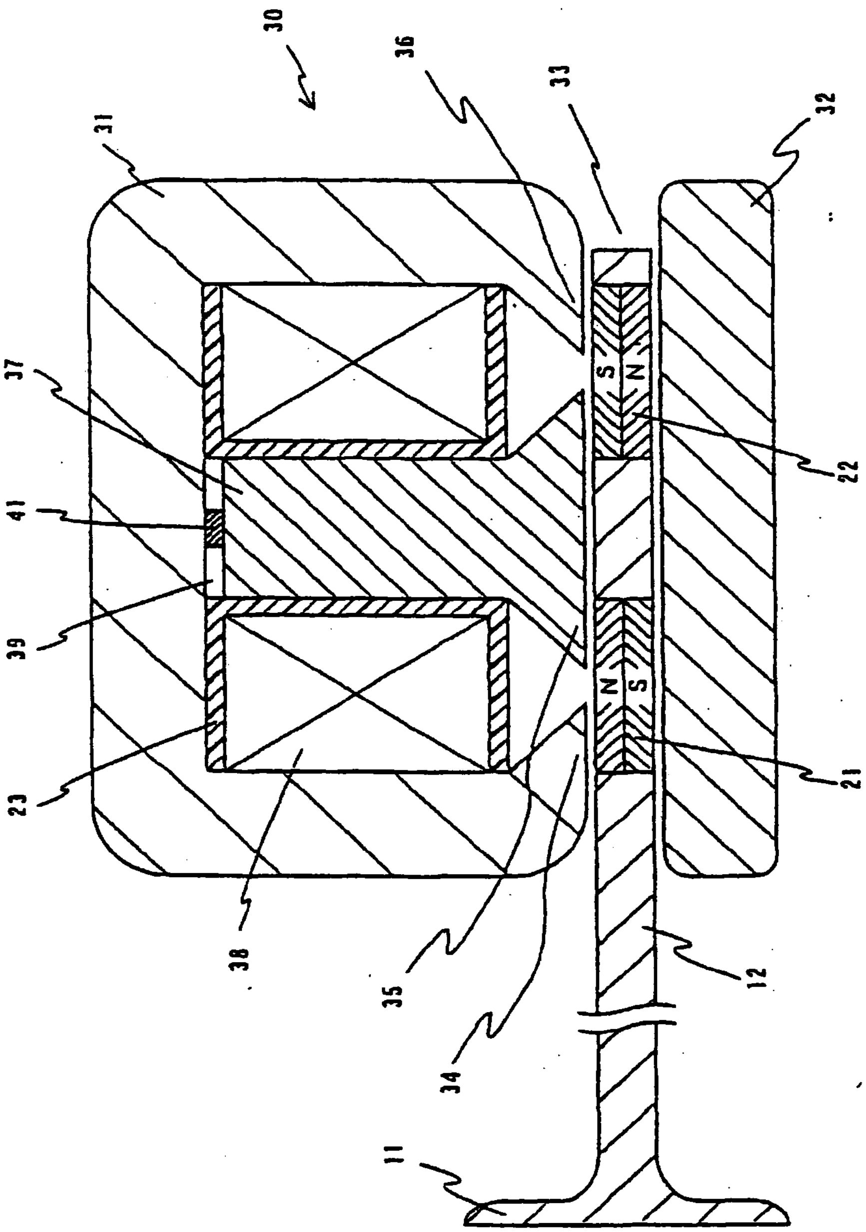

FIG. 7